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Heat Stressed State of Piston Engine Parts

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ABSTRACT: Modern foreign and domestic scientific literature has extensive information on the creation of a diesel engine with heat-insulated parts. Most of these studies are devoted to the development of technology for obtaining heat-insulating composite materials, methods for modeling thermal processes in internal combustion engines and reducing fuel consumption. Solving the problem of a diesel engine by reducing unproductive costs of thermal energy in the thermodynamic cycle and improving the performance of a diesel engine with heat-insulated parts based on the organization of the working process at high wall temperatures has not been sufficiently studied to date, which led to the choice of the topic of this study. In the Resolution of the President of the Republic of Uzbekistan (No. PP-4422 dated 22 August 2019) – "On Accelerated Measures to Improve Energy Efficiency in Economic and Social Sectors, the Introduction of Energy-Saving Technologies and the Development of Renewable Energy Sources", The President of the Republic of Uzbekistan Sh.M. Mirziyoyev noted that in order to comprehensively organize work to improve energy efficiency, widely introduce energy-saving technologies and renewable energy sources, radically reduce the energy intensity of economic and social sectors by involving available resources and untapped potential, taking into account advanced foreign experience, and also ensuring the rational and efficient use of fuel and energy resources. [1].

One of the most important concepts for a deep restructuring of the economic mechanism of the Republic of Uzbekistan is the creation of an integral, efficient and flexible system of economic management and the implementation on this basis of a program to improve the technical level and quality of machines.

KEYWORDS: Diesel Engine, Heat Stressed, Machines

INTRODUCTION

The car park of our country is increasingly replenished with vehicles with diesel engines. The development of modern diesel-engineering proceeds by forcing engines: increasing the average effective pressure and speed. Therefore, high reliability and service life, fuel efficiency and environmental performance are the main criteria for their quality. Forcing diesel engines leads to an increase in thermal and mechanical loads on the main parts of the cylinder-piston group (CPG) (piston, sleeve, cylinder head), a significant increase in their temperature, as well as the temperature of piston rings and valves. Overheating of parts is accompanied by the formation of temperature fields with a pronounced uneven distribution of temperature and, as a result, an increase in thermal stresses with a simultaneous deterioration in the mechanical properties of the material, the formation of cracks and, finally, the destruction of the part. In this regard, the task of protecting parts from excessive exposure to high thermal loads from the working fluid, or, in other words, the task of creating a diesel engine with reduced heat removal (DRHR) from the working fluid, becomes relevant.

However, the creation of a highly efficient engine with reduced heat removal from the working fluid is associated with the solution of a number of other issues, primarily with the provision of modern environmental requirements. First of all, this refers to the reduction of nitrogen oxides in combustion products while reducing the specific fuel consumption.

Taken together, these tasks constitute a major scientific and technical problem of great industrial and economic importance, since its solution makes it possible to increase the scientific and technical level of designing and creating new promising engines and obtain an economic effect by reducing the cost and costs of experimental development of diesel engines with reduced heat losses.

The temperature level of the main parts plays an extremely important role at all stages of the life cycle of piston engines, from design to operation. Since the thermal state of engines has a significant impact on performance indicators, including reliability, environmental and economic indicators, when developing engines, the most serious attention is paid to ensuring an acceptable level of predicted temperature performance indicators of parts by design solutions.

Diesel engines have become predominantly used on tractors mainly due to their high fuel efficiency. With the introduction of gas turbine supercharging, conditions have been created for further improvement of the working processes of tractor diesel engines and improvement of their specific and economic indicators. The use of turbocharging and charge air cooling made it possible to increase the liter power of tractor diesels to 15-17 kW/l and reduce the specific fuel consumption in nominal mode to 230 - 250 g / (kW h) [2,10,11,15].

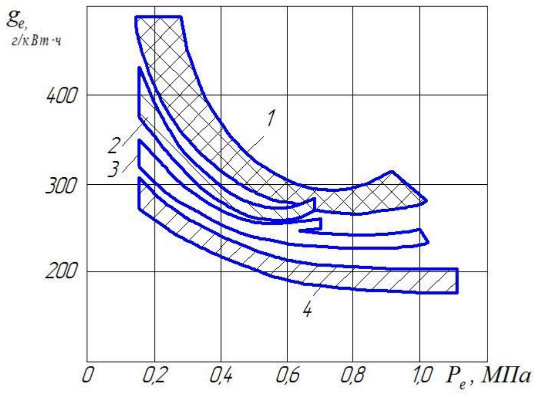

Fig. 1. Cost-effectiveness of internal combustion engines of various types. 1 - gasoline with injection into the intake pipe; 2 - pre-chamber or vortex-chamber diesel engines; 3 - diesel engines with direct fuel injection; 4 - diesel engines with turbocharging and direct fuel injection

As can be seen from fig. 1, the most economical are turbocharged diesel engines with direct fuel injection. Prospects for the development of modern diesel engineering are seen in increasing the average effective pressure of the cycle to 1.5-1.8 MPa, which will require the improvement of the working process through the optimal combination of combustion chamber schemes, the gas-dynamic situation in them and the parameters of the fuel injection process through the use of fuel supply systems with electronic control. This refers to the reduction of ignition delay periods, controlled and main combustion.

METHODS

An analysis of the factors influencing the formation of temperature fields of the main engine parts allows us to divide them into the following groups:

1) The flow of the working process, which determines the formation of thermal loads on the heat-receiving surfaces of the parts of the cylinder-piston group;

2) The use of parts of special design (the presence of thermal protection, screens, thermal barriers, means for regulating the intensity of the heat transfer process, thermophysical characteristics of the materials of parts, etc.);

3) Features of heat exchange processes in the combustion chamber and in the cavities of the cooling system (properties and thermophysical characteristics, flow regime and nature, state of heat carriers, state of heat-releasing surfaces, their temperature and vibration levels, the presence of turbulators and other means of influencing the intensity of heat transfer);

4) Features of technological processes for the production of parts (the presence on their surfaces of layers with special thermal and physical and mechanical properties);

5) features of time processes occurring in the engine (change in gaps, shape and state of heat-receiving and cooled surfaces, dynamics of formation of scale deposits, sludge, soot, varnish films, oxide films, actuation of additives to coolants, wear of parts);

6) Features of the engine operation, including its technical condition, observance of the rules of maintenance and repair.

RESULTS AND DISCUSSION

At the stage of development of new promising diesel engines, the first two factors associated with the organization of the in-cylinder process and the use of heat-insulated parts that form the combustion chamber are of particular importance. Therefore, this paper focuses on these factors. It should be emphasized that the nature of the working process directly affects the efficient and environmental performance of the engine, and the manufacture of heat-insulated parts requires the use of a special technology that

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takes into account the specifics of in-cylinder processes. In this regard, during the study, environmental issues were also considered, in particular, the formation of nitrogen oxides (the most dependent of harmful components on the temperature level of the working cycle) and the technology for producing composite powder, manufacturing compound heat-insulated parts.

The research of the factors listed above allows, when developing structures, to form a rational strategy for choosing control actions on the predicted level of temperatures of parts, taking into account the requirements for the engine. At the same time, control actions can be chosen diametrically opposite in terms of the nature of the impact on the temperature level of parts, depending on the set of leading, main indicators of engine quality. For example, there are technical solutions to increase the maximum temperature of the piston head up to 850-900 ºC by creating increased thermal resistance in the contact zone of the head with the trunk (engines with limited heat removal from the working fluid, forced VGM engines), while in other cases, they lower the temperatures of the parts by intensifying the cooling of the piston, or by using a thermally insulating material.

Recently, a large number of works have been carried out to increase the intensity of local heat transfer processes in the cavities of the internal combustion engine cooling system, the development of methods for modeling and calculating the parameters of local heat transfer in the cooling system, methods for optimizing the flow distribution in the cooling system, optimizing the shape of the temperature fields of parts of the cylinder-piston group (CPG) , methods for intensifying local heat transfer at critical points, methods for calculating the parameters of local non-stationary heat transfer in the combustion chamber of internal combustion engines (ICE) [3,4,5,12,17,18], development of means to improve the efficiency of heat exchangers.

At the same time, it should be noted that, despite the existence of a number of works on the creation of complex methods for modeling the totality of thermal processes in ICE (working process, heat exchange in the cylinder between the working fluid and the main parts, thermal conductivity, thermal state and force interaction of parts), the created models do not fully meet the needs of the practice of designing and fine-tuning modern engines.

The need to create a method for joint modeling of the working process and the thermal stress state of reciprocating engines is dictated both by the practice of ensuring the durability and environmental friendliness of internal combustion engines, and by the need to assess heat release and thermal boundary conditions. The latter are necessary for modeling temperature fields in various engine operating modes, since such boundary conditions for CPG parts are formed as a result of periodically repeating cyclic processes in the cylinder and on the surfaces of parts with relative motion of mating surfaces.

A complex of programs for personal computers, including programs for calculating the workflow, complex (radiative-convective) heat transfer in the combustion chamber, thermal and stress-strain state of parts, is a necessary element of the ICE computer-aided design system, the creation of which is being intensively developed in various countries.

With the participation of the authors, problem-oriented software systems were created for studying the thermal and mechanical stresses of internal combustion engine parts [6,7,8,9,10,13,14,16], as well as a complex mathematical model, which includes models of the working process of a transport diesel engine, heat transfer and heat-stressed state. Such a composition of the complex model corresponds to the logical relationship of physical processes in the internal combustion engine that affect the thermal and mechanical stress of its parts.

CONCLUSION

A promising direction in the development of modern engine building is to reduce heat transfer to the cooling system by thermal insulation of the walls of the combustion chamber. The nature of the working process flow, the use of parts of special design, as well as the features of heat transfer processes in the combustion chamber have a significant impact on the effective and environmental performance of the engine, the formation of temperature fields of CPG parts.

The creation of a method for joint modeling of the working process and the heat-stressed state of an engine with reduced heat removal allows, when developing designs, to form a rational strategy for choosing control actions on the predicted level of temperatures of parts, taking into account the durability and environmental friendliness of the internal combustion engine.

Using an integrated approach, you can solve the following tasks: optimize the working conditions of parts of a given design by influencing the working process; optimize the design of heat-stressed parts and assemblies, including parts with heat-insulating linings and coatings, with a given method of organizing the work process; check the functionality of structures. The use of such an integrated approach will reduce the preparation time for the production of new promising engines.

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